

SAM™ White Paper

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ADSL Overview and Growth

Asymmetric Digital Subscriber Line (ADSL) has become the mainstream form of DSL being deployed to the mass market. ADSL has long reach with service to over 80% of residents, high downstream data rates with acceptable upstream rates, low cost and extensive system interoperability with multiple sources of service. The number of deployed lines currently exceeds 350,000 with well over one million projected by the end of 1999; the year 2000 deployment estimates range from 6 million to 20 million. Over 2700 Central Offices (COs) have ADSL equipment which can potentially serve 26 million residents. Today many PC manufacturers including Compaq, Dell, and IBM are shipping ADSL ready products.

This market growth is due in large measure to the step by step elimination of the barriers to ADSL deployment. As with all new technologies, there was a battle over the standards to be used. In the end, both the ITU and ANSI groups ratified a form of ADSL based on Discrete Multi-tone (DMT) technology. The official ratification was completed in 1996. Since that time, all but one of the U.S. telecom companies (US West) have standardized on DMT and even this company is moving to DMT. An additional lower cost form of ADSL, called G.Lite, was ratified in June '99 by the ITU. G.lite provides an added incentive to deployment as it eliminates the need for the service provider to install a splitter in the home to separate data and voice. But it's not enough to have an established standard; multiple system providers must adhere to the same interpretation of the standard. Starting in 1999, multiple DMT based systems started to ship with extensive interoperability. At the June '99 SUPERCOMM show in Atlanta, numerous CO/CPE/chipsets proved they work together on this low cost G.lite form of ADSL. G.lite requires the telecom companies to upgrade their DSLAM software to handle both forms of ADSL; the telecom companies are in the process of qualifying new G.lite products with final qualification and testing of G.lite to be completed in late 1999. ITeX has shown true interoperability with over a dozen different vendors of Digital Subscriber Line Access Multiplexers (DSLAMS).

A second barrier was the Federal Communications Commission (FCC). There was large resistance to deployment until the Telecom Act of 1996 deregulated portions of the industry. Now most telecom companies including the Competitive Local Exchanges (CLECs) have the right to co-

locate DSLAMs in the CO and directly or indirectly sell (through ISPs) DSL service. In addition, these same telecom players are competing for business, amongst themselves and with DirecPC, cable, and wireless distribution (LMDS, MMDS), to offer broadband services. As a result, the economics of the service have become favorable to the consumer. Pricing in many areas is under \$50/month for 384-640 kbps service including Internet access. Equipment and installation costs can sometimes be waived with a 1-2 year commitment.

A technical barrier, spectral incompatibility, is being demonstrated to be a non-factor; when multiple high-speed lines are located in the same wire "bundle," performance can be severely degraded. However, with careful telecom deployment management, DSL, T1, and ISDN lines can be sufficiently separated with no significant reduction in bandwidth. With 25 full-rate ADSL lines in one bundle, trials show drops in downstream rates are less than one percent.

Deployment and equipment cost barriers are also being minimized. The G.lite standard eliminates the need for a technician to visit the residence. Line testing could take place on the CO-side with the end user installing and configuring a plug and play ADSL device. An additional source of cost reduction to the end user of G.lite is the ability to utilize a host or PC-based ADSL modem. To process a full-rate ADSL connection (8 Mbps) requires DSP or hardwired silicon. For G.lite speeds (1.5 Mbps downstream data rates), software with a hardware assist allows a PC to handle the processing on systems with no more power than a Pentium II or AMD K-6. The CPU utilization could be kept very low for lower download rates, creating the opportunity for a scalable technology such as ITeX's patent pending Scalable ADSL Modem (SAM™). Products based on scalable technology allow the user to select the downstream/upstream speed appropriate for their PC. ITeX's SAM is completely compatible with Windows 95/98/2000/NT and takes advantage of the ongoing shift to higher processing speeds. SAM technology is not limited to 1.5 Mbps because as the CPU power increases, full-rate download speeds are achievable at lower CPU utilization levels.

While the eradication of barriers to deployment is promoting heavy adoption of ADSL, the telecom companies are still left wanting. This new found business is causing new concerns to be dealt with. For instance, the service providers need to tie actual bandwidth received to access charges. Also, the new G.lite standard causes conflicts with G.dmt between the CO and CPE. SAM technology overcomes these issues by allowing a variety of new services and simplifies deployment.

Software-Based ADSL Technology

SAM technology allows the user to obtain download speeds appropriate for the PC used and the CPU utilization deemed acceptable. A Pentium III, 500 MHz product will use 17% of the CPU for 1.5 Mbps downstream and even less for the newer higher speed processors.

SAM technology is accomplished by the optimized partitioning of DSL processing into hardware and software. A complete software solution would be impractical due to the increased use of the CPU or causing much higher PC costs through the use of more powerful processors to keep utilization to acceptable levels (under 25%). SAM achieves this balance by placing all "tone-related" functions in hardware and most other functions on the host CPU. Tone functions such as fast Fourier transforms are simply redundant DSP intensive algorithms best done in hardware. This allows a combined ADSL modem and CPU to achieve the lowest total cost solution. Not only will this "hardware assist" give improved performance over a complete software solution, but it will also enable "accelerated G.lite" speeds. SAM technology allows essentially unlimited bandwidth scaling. With the soon to arrive Pentium III 700 MHz systems, existing AMD K-7 PCs and eventually, 64-bit based processors, "full-rate G.lite" will be possible at a considerable cost savings. Additional benefits of host processing include leveraging host memory for data interleaving and processing performance-monitoring statistics. With users still buying 56K V.90 modems, SAM technology also allows simultaneous operation of both V.90 analog as well as ADSL modems; hardware DSP-based solutions have a "single point of data contention" at the DSP and switching from one type of connection to the other usually requires a system re-boot. SAM technology does not have this limitation.

While lowering cost is a major factor pushing deployment, ITeX's SAM technology adds many features beyond those well known in the full-rate G.DMT and G.lite specifications. The original G.dmt/992.1 specification provides standards to offer traditional full-rate ADSL service and ensure interoperability. For incumbent and CLECs to offer basic service, the specification is adequate. But SAM technology goes beyond "basic service" and allows new types of offerings as well as improved management of ADSL service. SAM technology allows scalable downstream rates, auto channel selection, power management, auto detection of G.lite/G.dmt/ANSI T1 Issue 2, "G.lite+", rapid retrain, dying gasp, complete WAN protocol support, and added diagnostics. These features enable many ways for the multiple service providers to differentiate themselves and expand the total market.

Enabling new ADSL services/deployment options

Allowing selectable downstream/upstream rates will enable a true "pay-for-bandwidth" service. Current systems essentially are limited to either 384kbps to 1.5 Mbps or 1.5 Mbps to 6 Mbps with the actual throughput depending on the line conditions, wire gauge, distance, and "crosstalk" from alternative high bandwidth services. Typically the service provider will know the minimum guaranteed rates and anything above this is a bonus. Pricing is based on this minimum and anything above this is "free". However, "one size rarely fits all". SAM allows the user to select the bandwidth they are receiving and is priced accordingly by the service provider. Provided the rate selected is achievable, the provider can offer the selected rate at a particular price. With rates scalable to 32kbps increments, the user can determine the rate they are willing to pay. The software and hardware architecture in SAM allows for this rate selection. If the user wants "G.lite+" speeds, they can pay for this as well. Since pricing is usually "exponential" with rates, the user, not the service provider, can determine the best rate based on CPU usage, rate needs, selected server bandwidth, etc. Since actual WAN throughput currently varies between 400 to 800 kbps, the user may "dynamically" select rates depending on the server they are addressing. At the same time, the provider is not giving away "free bandwidth". Additional competitive pressures will occur which will lower pricing. As the WAN is expanded to over 98 terabits/second of capacity by 2002, rate "specials" perhaps based on the time-of-day, Internet backbone utilization, or other factors will occur.

By implementing Auto Channel Selection, data throughput rates will be improved and line dropping minimized. Within the current implementation of full-rate ADSL, 256 channels are used to send data; these channels range up to 1.1 MHz. Yet degradation of data transmission increases with higher frequencies. To reduce increased noise, G.lite, inspired by SAM technology, adopted the use of the lower half of this frequency spectrum. SAM allows the user to actively reduce the bit loading per channel as well as eliminate use of the higher frequency channels within the G.lite range. This channel selection process can reduce the likelihood of a dropped line at a given bandwidth. If a user has a particularly noisy line or multiple phones in the home, which can increase chances of line dropping, they can select an optimized setting for this environment. With few or no other lines in the home, the user can be more "aggressive" and obtain better bandwidth. While most users will not be likely to change automatic settings, over time, better graphical user interfaces will simplify user control.

ADSL CO equipment can consume a lot of power. A typical DSLAM will have over 500 line terminations in one system. Multiply that by multiple systems with about 3-4 Watts per line and you have significant heat generation. Digital Loop Carrier (DLC) deployment will be particularly

affected by power. SAM technology allows for superior power management control. Utilizing SAM technology in the central office can reduce power consumption, minimize cooling system needs, increase DSLAM density, help enable DLC deployment, etc. With the space availability at most CO sites fixed, this increases the number of DSLAMs and overall DSL service.

With G.lite, ANSI T1 Issue 2, and G.dmt hardware/software deployments in the CO, there is an advantage to a technology that can automatically determine which type of system the modem is connected to. With SAM technology, the users CPE system can detect which system is in place and automatically connect with that system. Prior to SAM, a user's modem would have to be matched with the CO site. This causes additional management issues and confusion for the user. As the user relocates, the issue will be repeated. In many instances, the CO may not be equipped with both services, thereby forcing deployment by the telecom provider. SAM's auto detection functionality virtually guarantees that the modem will work with the CO. The end-user task is simplified as this detection/configuration of the ADSL modem is done automatically. Telecom providers can even reduce or eliminate G.lite deployment, as SAM-based modems will work with either type service.

The G.lite standard has many advantages. However, the drawback is lower speeds (with a peak at 1.5 Mbps) and potentially dropped calls. ITeX's SAM technology eliminates this rate limit by allowing rates well above 1.5 Mbps. This "G.Lite+" capability gives the benefit of connections pushing full-rate at a much lower cost. Current deployment of G.lite-only modems will be obsolete if line conditions or distances improve. ITeX's G.lite+ based modems will not need higher operating frequencies and are subject to less attenuation with distance; the bandwidth-reach "product" will exceed standard offerings. The likelihood of dropped calls is reduced by SAM technology's "fast retrain" function. Once a call is dropped, SAM does not reinitialize the call from the beginning, but rather uses parametric data from the first connection to quickly establish bit loading, rates, etc. By getting a head start, the new connection can occur in a few seconds. The user is typically unaware the call was dropped. Dropped calls usually result from impedance changes that occur when calls on other lines are answered. In-line filters are used to reduce this effect at low cost; rapid-retrain can reduce the performance needs and the small cost of these filters or eliminate them all together.

SAM provides other call management support. When a call is dropped by a power loss on the CPE-side, the CO will not know for a period of time and processing time/power is wasted on a dropped line. SAM technology provides a "dying gasp" feature that notifies the DSLAM that the

line is going down before it is completely dropped; the CO then knows which modems are no longer active and drops support to this modem. Hence, better call termination management.

Current ADSL deployment utilizes multi-protocol over ATM (RFC 1483). This is shifting in some cases to RFC 1577 and eventually point-to-point protocol over ATM. In addition, current implementations use Permanent Virtual Circuits (PVC), which makes it much more difficult to handle new users and calls. Switched Virtual Circuits (SVC) is preferable due to its dynamic call switching. The telecom industry will move to SVC by 2001. ITeX's SAM solution has all these protocols and switching technologies covered with complete support. As infrastructure changes are made, the customer modem will continue to operate without software downloads or hardware changes. If a change is required, the software nature of SAM allows modification.

SAM provides enhanced diagnostic functions useful for both the end user and service provider. With a sophisticated, yet easy to use graphical user interface, the user can monitor performance, actual downstream and upstream data rates, CPU utilization, line quality, total transmitted and received bits, etc. As a first step in solving connection issues which may occur, the user can run available straightforward system and hardware tests. More advanced diagnostic tools allow administration and maintenance capabilities as well as provide average signal-to-noise ratios, average bit-loading per channel, error count statistics, upstream/downstream spectrums, and multi-tone generator information. By using these advanced tools, the user or system provider can isolate and correct system or line connection problems very quickly, often without a service call.

Conclusion

Now that ADSL deployment is well under way, it is only natural that the service providers want to expand beyond current basic service. SAM technology provides numerous approaches for enhanced service, higher profitability, and simplified call management. ITeX has taken a leadership position in this new ADSL technology with its patent pending SAM product line. Through utilization of ITeX's SAM IC architecture and software support, ISPs and Telecom companies can receive true revenue for bandwidth, simplify CPE/CO interoperability, improve "always-on" reliability, and cut equipment costs.